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Residential solar photovoltaic market stimulation: Japanese and Australian lessons for Canada

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Abstract

Canada is a leading electricity consumer, yet lags behind other industrial countries (14th out of 20 reporting IEA countries) in the installation of solar photovoltaic systems. The factors (environmental benefits, health benefits, network benefits, need for new production capacity, etc.) promoting solar or other renewable sources of electricity in other countries are also present in Canada, but effective policy mechanisms to stimulate Canada's photovoltaic industry are only starting to appear. Discussions of policy options focused initially on renewable portfolio standards and then on feed-in tariffs. This paper reviews the Japanese and Australian experience with capital incentives to stimulate the residential market for photovoltaics. It demonstrates the ability of a market-sensitive program to stimulate industrial growth, achieve unit cost reductions and shift the market to include a large grid-tied share. Residential respondents to surveys report high costs as their primary barrier to installing photovoltaic systems and state a strong preference for capital incentives to reduce their investment costs. The Canadian government needs a market stimulation policy if it is to join those countries where a decentralized photovoltaic generation system strengthens the electricity supply system. A balanced solar energy market stimulation program is proposed that combines a feed-in tariff with a declining capital incentive.

Keywords: Solar energy policy; Photovoltaics; Residential market

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1. Introduction

This article reviews capital incentive programs for solar electricity or photovoltaic systems in Japan and Australia and contributes to current renewable energy policy discussions in Canada and its most populous province, Ontario. The distinct, yet overlapping, interests in federal climate change policy and provincial electricity supply arrangements are noted, yet solar electricity generation is only a marginal consideration in these discussions. The growth potential of solar photovoltaics and the penalties of being a laggard in developing this new technology have been widely recognized [20]. To move Canada from a position of a photovoltaic laggard to effective market, transformation requires a review of solar photovoltaic policies in more advanced solar countries. Proposals have been presented to encourage the photovoltaic industry, but they have focused on the renewable portfolio standard and feed-in tariffs. Photovoltaic market stimulation has also been achieved through capital incentive programs in other countries and a review is required to consider the implications for Canada.

This paper briefly reviews recent discussions on the evolution and timing of policy options in stimulating photovoltaic and other renewable sources of energy. The policy contexts of the Japanese, Australian and Canadian photovoltaic markets are examined. Japan combined energy and industrial development objectives in its national market stimulation programs for residential photovoltaic systems. The smaller Australian capital incentive program is examined with attention paid to the changes in the share of grid-tied installations that it stimulated. The implications of this experience are then considered in the Canadian context. A capital incentive program is identified by residents as the preferred means to overcome the high cost barrier they face when considering solar electricity options for their homes. The paper then integrates the lessons from the policy reviews to propose a balanced market stimulation program to stimulate the photovoltaic market in Canada. Rather than consider the policy options as mutually exclusive, three scenarios are considered. The first scenario is based on the Canadian Solar Industry Association's (CanSIA) proposal for a feed-in tariff. The second mirrors the Australian capital rebate program, while the third combines a feed-in tariff and capital rebate as a balanced market stimulation program that reflects the benefits of photovoltaic investments to different parties. An attractive feed-in tariff could stimulate investment to help meet

provincial decentralized electricity supply needs while a capital incentive program would encourage faster industry development and greater reductions in greenhouse gas emissions. The conclusion endorses this combined policy approach that includes incentives for market stimulation.

2. Policy evolution

Renewable energy technologies vary in price and performance over time. Improved performance and reduced cost have been achieved with the evolution of technologies and improvements in the production, distribution and installation of products. Two examples of renewable energy technologies that have greatly reduced their unit costs over the last two decades are wind turbines and solar photovoltaic panels [36]. Improved designs and economies of scale have been achieved, but the challenge remains to move the industry from an initial position of high unit costs and a marginal place in the energy industry of many countries to lower unit costs and larger market shares.

A variety of policies have been used in different jurisdictions to promote the adoption of new energy technologies and to initiate a transition from conventional sources to renewable sources of energy. An important discussion has arisen regarding the preferred type of policy for the stage of development of the industry [16,23,33]. Rowlands [33] supported Lauber [23] in the assessment that generous feed-in tariffs (incorporating the external costs avoided by the new technology) can better stimulate the market for photovoltaics at an early stage of development than renewable portfolio standards which are better suited for a more established technology. In contrast, Haas [16] regarded feed-in tariffs as better for a middle stage of market development where the technology has reached a stage of maturity. Many European countries have introduced feed-in tariffs to encourage investment in solar and other renewable energy sources [27]. Germany, Austria and Spain are notable success stories in the development of their solar industries while Finland, Greece and Italy have had less success [33]. Despite optimism when policies are drafted and targets set, actual uptake may lag behind targets so a systematic review of national approaches is called for [17].

Advanced feed-in tariffs pay higher fees for the electricity generated in recognition of its time-of-use value (production at peak demand times associated with air conditioning loads), its distributed benefits (avoiding investment in network capacity to meet peak demand during high temperatures) and the avoided environmental costs (associated with poor air quality and greenhouse gas emissions). Assessments by Americans for Solar Power [1], an industry-based group, estimated the value of the ancillary benefits from distributed photovoltaic generation at $US 0.22/kWh [31].

Despite the long stream of benefits associated with a feed-in tariff, many homeowners consider the high capital cost to be the major barrier to acquiring photovoltaic systems. This barrier can be addressed directly by providing capital incentives to reduce the direct cost to homeowners. Capital cost subsidies have been used in Japan under the Residential PV Dissemination Program and the 100,000 Roofs Programme in Germany to reduce investment costs [14]. Capital incentives are argued to be especially important at the very early stage where the new technology is not competitive with conventional energy sources. Some governments oppose incentives because of their ability to distort markets. However, many financial policies from differential depreciation rates to exploration incentives and public liability for waste disposal have shaped, and continue to shape, the conventional

energy industry. The key is to link the policy to the appropriate issue. For example, feed-in tariffs have been argued as an appropriate means to recognize the environmental, health and system benefits offered by renewable energy sources [23,33]. Similarly, capital incentives are appropriate as temporary measures to stimulate demand that enables the industry to gain experience, achieve economies of scale, reduce unit costs and thus become competitive in the new market.

One of the most successful countries at stimulating and nurturing new industries that grow to become competitive at the global scale is Japan. From early experience in electronics and robotics, the Japanese government's support of the photovoltaic industry in the 1990s and early 2000s is simply the latest example of a well-established pattern. Incentives are offered to stimulate the development of markets and competing producers are expected to respond by reducing their costs over time. The key feature is that the incentives are transitional and that the industry becomes competitive as the incentives are reduced. The example of the Japanese support of photovoltaics in the residential market illustrates the process and its key features.

3. National energy policies

The Japanese Ministry of Economy, Trade and Industry (METI) was credited with playing an important role in the development of Japanese industry [22]. Given the history of the ministry focusing its development policy on industries needed to meet contemporary political objectives, it is no surprise that the prominent role Japan assumed by having the Kyoto Protocol negotiated and signed in Japan also created the context for METI to support the development of industries that could reduce greenhouse gas emissions while also supplying Japan's growing energy needs. The Kyoto Protocol to the United Nations Framework Convention on Climate Change set greenhouse gas emission reduction targets for industrialized countries. Japan signed and ratified the Kyoto Protocol with same target as Canada—to reduce greenhouse gas emissions to 6% below 1990 levels by 2008–12. However, by 2002, Japan's emissions had increased 12% above its 1990 base [37].

The broad goal to reduce greenhouse gas emissions is clearly identified as one of METI's reasons for the support of renewable energies. Another goal is to increase the security of Japanese energy supply above its current 20% level (including nuclear) [29]. This energy security goal is consistent with energy policies promoted since the 1970s.

Japan has limited conventional energy resources so the energy crisis of 1973 stimulated the creation of the Sunshine Project in 1974 to encourage non-oil energy sources. Although, the original Sunshine Project did not identify photovoltaics as a new source of energy for support, the Moonshine Project (introduced after the second energy crisis) included photovoltaics and in 1980 the New Energy Development Organization (NEDO—later renamed New Energy and Industrial Technology Development Organization) was created [18]. The New Sunshine Project was created in 1993 from a merger of the old Moonshine Project and from a research and development program for environmental technologies that had been launched in 1988. It highlighted the potential for photovoltaics as a national source of energy [33]. The Council of Ministers for the Promotion of Comprehensive Energy Measures established the 'Basic Guidelines for New Energy Introduction' in December 1994. The Basic Guidelines seek to reduce dependence upon imported oil and to meet the 6% reduction target set under the Kyoto Protocol [21]. The initial plan was to achieve these goals through a combination of new energies, energy

conservation and increased nuclear power generation. The 1998 'long-term energy outlook' set the 2010 target for installed capacity of photovoltaic systems at 5000 MW [18].

By the end of the first phase of the New Sunshine Project in 2001, public support for increased nuclear reliance had declined and greater emphasis was placed on new energies with photovoltaics expected to provide one-half of the new energy capacity. In 2001 the New Sunshine Project was replaced with the Advanced PV Generation programme. In addition, the 2010 targets for the photovoltaic industry set in 1994 were revised with a longer and more ambitious view to 2030. In July 2004 METI published a report on Japan's energy future to 2030 in which renewable sources were to account for 10% of total energy needs, and over half of the renewable energy (80 GW) was to come from photovoltaics. NEDO set Japanese photovoltaic targets of 4.8 GW installed by 2010 and 100 GW installed by 2030 [12,13]. Critics of the targets set in the documents claimed that they were too high to be fulfilled, but the target of 400 MW installed capacity set for 2000 was achieved in 2001, indicating remarkably little slippage in the early phase of an ambitious program [21]. Achieving the target of 4.8 GW in 2010 would also provide the environmental benefit of offsetting the annual emission of 5 million tonnes of carbon dioxide, assuming that coal-fired plants are displaced [29]. Even the business-as-usual scenario expects 2.5 GW of photovoltaic capacity by 2010. Several policies were introduced to achieve this growth.

The Renewable Portfolio Standard Law was passed by the Japanese parliament in 2002 and enforced by METI in 2003 [19]. Six types of renewable energy were identified (solar, wind, terrestrial heat, hydro and sources that the government specifies (e.g. biomass and waste) and electricity retailers are to set annual targets for each. The 'new' energy share of total power supply is to treble to 3.2% in 2010 [21].

The 2002 National Energy Framework Law was based on three principles: a stable energy supply, environmental friendliness, and the use of market mechanisms [29]. Photovoltaic technology offered a means to achieve the first two goals, but how was it to be achieved through market mechanisms? The residential market illustrates how a market-sensitive policy was developed to stimulate a new industry.

3.1. Residential photovoltaic market in Japan

> Japan has found a good balance between costs for individual consumers and state spending [14, p. 18].

A series of programs were implemented to promote the residential installation of photovoltaic systems. The New Energy Foundation managed the first program 'Monitoring Programme for Residential PV Systems' from 1994 to 1996. The program paid 50% of the installation costs and the number of households participating rose from 539 in 1994 to 1986 in 1996 [21]. The total annual cost of subsidies doubled from 2 to 4 billion yen, but unit costs declined as hoped. In 1997 a larger program 'Programme for the Development of the Infrastrucutre for the Introduction of Residential PV Systems' was launched with a larger budget (rising from 11.1 billion yen in 1997 to 23.5 billion yen in 2001). However, individual subsidies declined from 340,000 yen/kWp (kilowatt peak capacity) to 120,000 yen/kWp over the same period. With average annual electricity production levels of 950 kWh/kWp (kilowatt hours per kilowatt hour peak capacity), the average electricity savings amounted to 23,400 yen/kWp [21]. These savings of approximately 70,000 yen/year for a 3 kWp system were modest compared to investment

costs, so the lowering of initial capital costs was a critical feature to successfully stimulate the market.

In Japan, subsidies were seen as a temporary measure to stimulate demand in the market so that new technologies could be introduced and production levels increase to a scale where unit costs were reduced. The resultant industry would be expected to be viable without subsidies. The planned reduction of national subsidies has been underway for over a decade (1994–2005) with 2006 marking the end of subsidies under the residential (RPVDP) program. The relationship between subsidized price and actual price is shown in Fig. 1. Although the subsidy has decreased substantially over the decade, the actual price has fallen by a similar amount with the result that the net price paid by customers has remained largely unchanged, just under 2 million yen for a typical system. In this context, the fear that the market might collapse with the end of the national subsidy program is unlikely to be realized. Instead, capital incentives stimulated demand, increased the size of the market and resulted in reduced unit costs.

The question "Did incentives influence the market?" is clear. Yes, they stimulated demand. However, the growth in sales over the decade as incentives decreased shows that a simple positive relationship between incentive level and sales did not exist. Instead, sales rose as national incentives declined. The stable net price faced by the consumer and their increasing confidence in the technology contributed to market success. The introduction of an incentive program can also change market shares as shown in Australia.

3.2. Australian photovoltaic rebate programme

The Australian Photovoltaic Rebate Programme provides a modest example of the impact a capital rebate system can have. The programme provides a capital rebate for photovoltaic systems installed on residential or community use buildings. The programme began in January 2000 and was extended in 2005 to June 2007 [3]. Since 2002, approximately 1000 installations have been supported each year with residential projects accounting for 95% of the total.

The Australian rebate was valued at \$4/Wp for a new system or \$2.50/Wp for an expansion, however, thresholds also applied. Systems must be over 450 W in size and only the first 1000 W counts for the residential rebate (2000 W limit for community

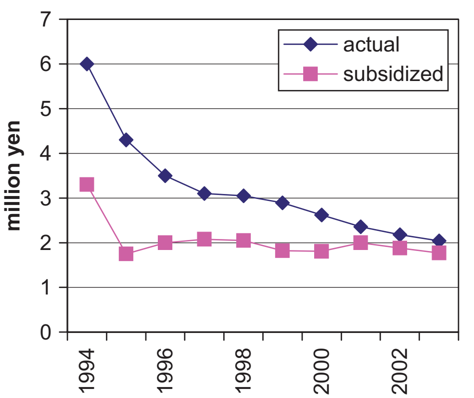

Fig. 1. Residential 3 kW photovoltaic system prices in Japan [34].

installations). The program was extended in 2005 with the intention that it would be phased out over 2 years with the incentive declining in a series of $0.10 steps from $4.00/Wp in 2005 to $3.50/Wp in June 2007 [3]. The average size of grid-tied residential systems grew from 1.3 kWp in 2000 to 1.7 kWp in 2005. The program supported the installation of 8.3 MWp of generating capacity in its first 6 years.

Incentive programs can help develop new market segments for new technologies. The higher cost of photovoltaics in comparison to conventional sources of electricity resulted in its use primarily in specialized off-grid applications in Australia. When the photovoltaic rebate program was initiated in 2000, only 16% of the residential systems receiving the rebate were connected to the grid. In 2003, grid-tied systems exceeded those off-grid, and by 2005 65% of the systems were grid-tied (Fig. 2). This transition in the market is of special interest to the Canadian industry because Canadian photovoltaic installations are primarily off-grid (remote and recreational markets) [8]. The ability to capture a share of the grid-tied market would open much larger market opportunities and also create the network benefits of having a distributed generation system.

3.3. Canadian policy context

> The primary reason that Canada is behind (other countries in solar installations) is the lack of government programs to support the initial deployment of PV and to help reduce market entry barriers. Solar can be a major source of electricity generation in Canada—but it needs government support to develop its markets [9, p. 3].

Canada has a long history of having one of the world's most electricity intensive economies. Abundant fossil fuels and hydro-electric power plants have enabled the residential cost of electricity to be kept low (typically US $0.06–$0.09/kWh). In this context, solar photovoltaic electricity is considered competitive only in remote or off-grid settings. However, the climate change consequences of large-scale fossil fuel combustion are widely recognized, so the Canadian government ratified the Kyoto Protocol in 2002 and established a Green Plan to meet its target—6% reduction below 1990 levels [6]. In 2006 a minority Conservative government was elected that said the Kyoto Protocol

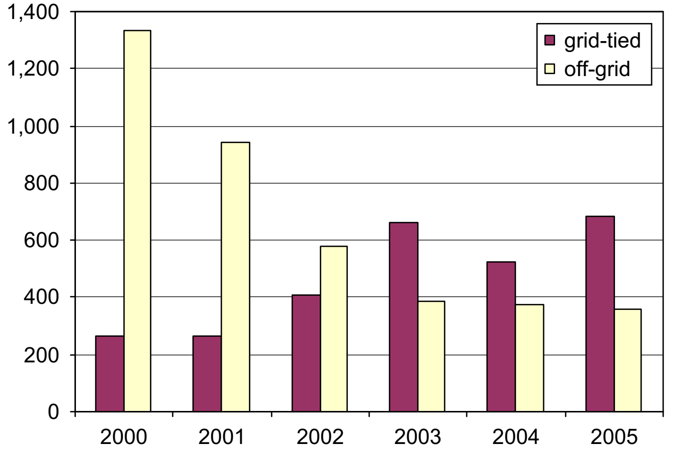

Fig. 2. Residential systems in the Australian Photovoltaic Rebate Programme [4].

target was not achievable, declared the previous government's Plan to be ineffective and cancelled 15 associated programs [10]. The assertion that Canada's Kyoto target was not achievable was to be followed by the introduction of a more effective set of policies, but the Government and Opposition parties disagreed over the desired policies.

Fossil fuel combustion for transportation and electricity generation also caused urban air quality problems and record numbers of poor air quality days were recorded [26]. In 2004 the newly elected Ontario government announced its intention to close all of its coal-fired power plants by 2007. Subsequent delays in the proposed dates for closing the largest plants have been criticized and the Ontario Power Authority recommended that the plants remain staffed and ready for use even if they are normally off line.

The challenge faced by the provincial government was compounded by problems at some of the aging nuclear reactors requiring their removal from the grid for refurbishment or closure. Nuclear, fossil and hydro sources of electricity dominate the Ontario system and new capacity is required to meet growing demand. Some expansion in hydro-electric capacity is underway with the expansion of the Niagara hydro generating station, but the system is expected to need investment for additional supply capacity of over 20,000 MW by 2030 [24]. Sales tax exemptions are expected to help renewables (including solar) play a small role in this expansion [25].

The peak demand for electricity to supply growing numbers of air conditioners in summer creates a peak price for electricity at a time when photovoltaic panels could provide a valuable supply. Distributed generation systems have long been promoted as a solution to many of the current system problems and residential solar photovoltaic systems could provide part of the solution. However, the Ontario Power Authority does not expect distributed residential photovoltaic systems to provide a significant source of electricity [7].

In Canada, a few grid-tied houses have installed photovoltaic systems, but they are widely scattered across the country. The federal government agreed to support a proposal to create a solar neighbourhood of 12–15 solar houses as part of its Technology Early Action Measures program to address climate change [5]. The Eastbridge on the Grand subdivision in Waterloo was developed by a builder (Cook Homes) with solar experience and a partnership was formed with ARISE Technologies, the solar supplier, and others [2]. Many factors affected the rate and timing of development, but the overall result was that only four of the 80 homes built by Cook Homes included the solar electricity option. A survey was taken of homeowners in the subdivision and a clear message given as to why they had not selected the solar option. The most common reason respondents gave was cost (71%) followed by skeptical about the technology (10%). When asked what the general barriers to purchasing solar houses were, 83% of respondents replied cost. When asked what would be required to motivate them to purchase a solar home the top two responses were lower cost and financial incentives [15]. These responses are consistent with those found in other countries and the barriers reported to investment in residential energy efficiency [30].

In contrast to studies which propose a single mechanism to stimulate a market for a new technology, this paper proposes a balanced approach that incorporates complementary instruments to encourage investment by multiple stakeholders.

4. Proposed balanced market stimulation program

CanSIA called for an ambitious program of 25 MW installed capacity by 2025 and all new houses being equipped with 3 kWp photovoltaic systems [8]. This view of the future

stands in contrast to the electricity industry expectations that reveal a very minor position for solar energy [27]. Even achieving the optimistic growth target of the industry to 1.4 MW annual installations by 2010 in Ontario or perhaps 4 MW nationally would still result in the Canadian installation rate being eclipsed by Japan by a factor of 1000 [9,12]. If the photovoltaic industry is to be a significant player in Canada's move to a less carbon intensive future, new policies and mechanisms are required.

One way to stimulate the solar electricity industry is to offer a higher price for the electricity generated that recognizes its environmental, health and system benefits. The Ontario Sustainable Energy Association proposed a tariff of \$0.83/kWh in a 20-year contract [28] and CanSIA proposed a more modest tariff of \$0.42/kWh in a 10-year contract that represents an estimated 40% subsidy [9]. CanSIA proposed a tariff level to stimulate modest growth in the industry and stated that additional incentives may be required to achieve higher growth rates.

In Ontario, CanSIA [9] estimates installed photovoltaic costs at \$10/Wp, or \$30,000 for a 3 kWp system. The Net Zero Energy Home Coalition expects this price to decline to \$16,000. The lower price would stimulate much greater demand, but it is not expected to be achieved for many years. The government could encourage that demand earlier by offering a subsidy of 50% of the cost (similar to the Japanese program of the 1990s). Alternatively, a combination of capital incentive and feed-in tariff could be designed. An incentive of \$3.00/Wp, or \$9000 for a 3 kWp system, would reduce initial investment costs and when combined with a feed-in tariff over 20 years would generate significant interest.

This proposed balanced market stimulation program would encourage private investment in solar electricity production capacity by offering a declining capital incentive. The incentive could start at \$3.00/Wp installed and decline by 10% or \$0.30/Wp each year until it reached zero at the end of the decade. Market stimulation would remain as the reduction in public incentive would be offset by an expected 3–5% annual reduction in industry costs as capacity grew and unit costs declined [32,35,36]. In this way, the capital cost to the consumer remains stable while the contribution from the government declines over time. In addition, the CanSIA proposal for a feed-in tariff of \$0.42/kWh should be implemented to recognize the benefits of increasing the solar share of the supply mix. These measures would encourage private households to make capital investments in this solar capacity. The government would stimulate the market by sharing investment costs (30% initially) for the young industry, but reduce its incentive as the industry matured. Scenarios comparing these alternate trajectories are presented next.

4.1. Alternate scenarios

The general description of the balanced market stimulation program can be illustrated by comparing three scenarios of programs to stimulate the solar industry in Ontario. Scenario A is the proposal by CanSIA [9] to provide a feed-in tariff of \$0.42/kWh and served as the basis of the Ontario government's announced standard offer contract. Scenario B is similar to the Australian program with an initial capital incentive of \$4/Wp (declining in steps to \$3.50 in 2016) supporting 1000 installations annually. Scenario C combines a feed-in tariff of \$0.42/kWh with a capital incentive declining from \$3/Wp to stimulate more rapid growth in the early years.

Each of the scenarios assumes significant growth in the number of residential photovoltaic installations over 10 years (Fig. 3). Scenario A shows rapid growth from

the industry's activity level of only 50–60 installations in 2005. The launch of the program increases installations to 90 in 2007 (the assumed first year of the program) and this grows to nearly 4800 in 2016 for a total of 15,000 installations over the 10-year period. In contrast, Scenario B assumes that 1000 installations are supported each year. The limited capacity of the Canadian industry makes achieving this target difficult at the start of the period, so the 2007 value is halved to 500 installations. The overall result is 9500 installations during the 10-year period. Scenario C combines the feed-in tariff and a smaller capital incentive. The result is more rapid growth during the early years, the installation of nearly 7000 units in the final year and 23,000 installations over 10 years.

The average size of residential installation is also expected to grow. The CANSIA study forecast gradual growth in size from the current average Canadian size of 0.9 kWp in 2006 to the international standard of 3 kWp in 2013. Scenario B assumes the same increases in average size while Scenario C assumes more rapid growth with the 3 kWp average achieved in 2010.

The resulting installed capacity of the photovoltaic systems is shown as cumulative capacity (Fig. 4). Annual installations grow to 14 MWp under Scenario A, stabilize at 3 MWp under Scenario B and grow to nearly 21 MWp in 2016 under Scenario C. The cumulative capacity installed is 41, 20 and 68 MWp under the three respective scenarios. Although small compared to Japan, this represents substantial growth of the installed photovoltaic capacity in Ontario.

The annual electricity production is calculated assuming 1.2 kWh/year/kWp [9]. The annual production grows from modest beginnings of <1 MWh in 2007 to 50, 24 and 82 MWh in 2016 under the three scenarios (A, B and C respectively in Fig. 5). Although the total output is modest in comparison to total Ontario demand, the timing of production is significant as it matches the peak air-conditioning demand and the highest prices or value of electricity during summer.

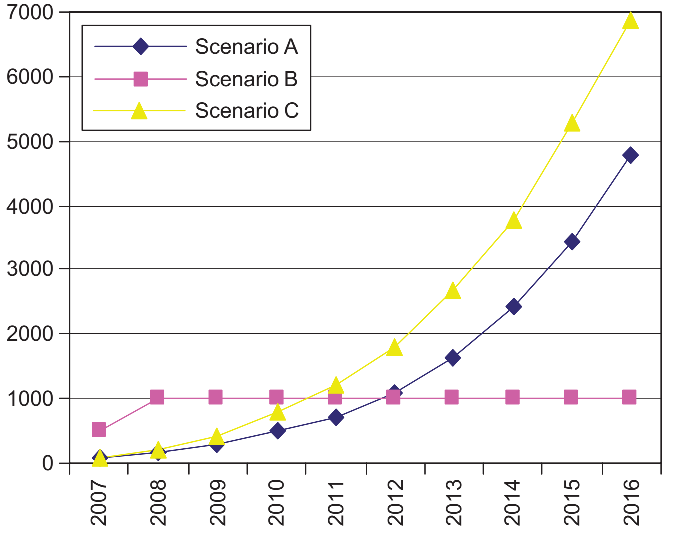

Fig. 3. Annual residential installations by scenario.

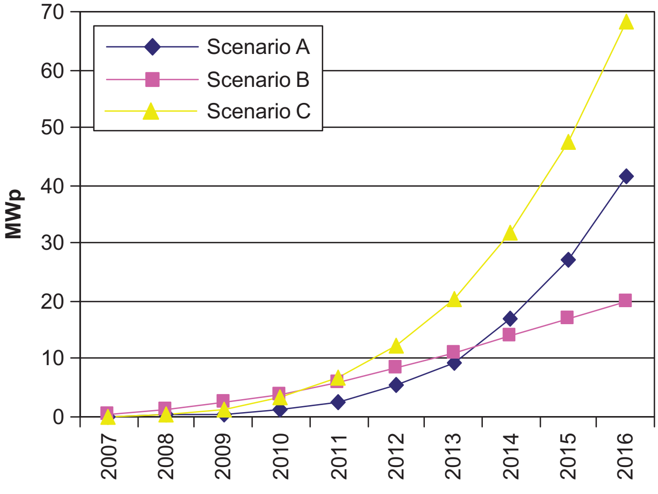

Fig. 4. Cumulative capacity by scenario, MWp.

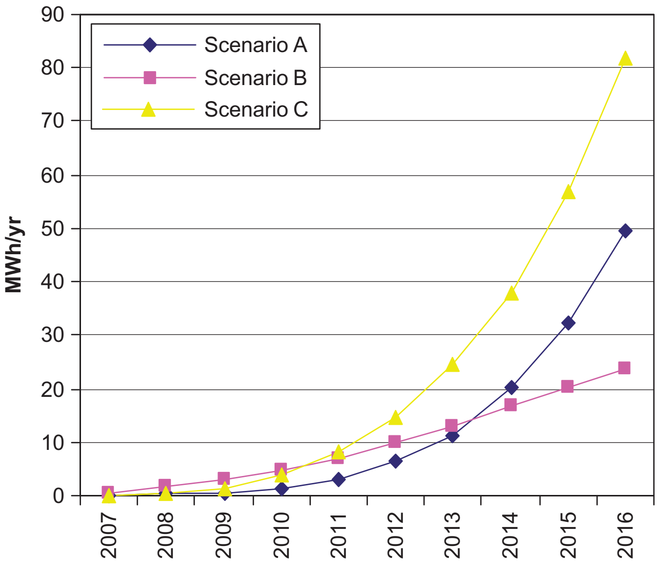

Fig. 5. Annual electricity production, MWh.

The annual cost of achieving this production is first calculated in terms of the net feed-in tariff paid. In each case, it is assumed that the tariff applies for 20 years. No adjustments are made for inflation. Scenarios A and C assume the feed-in tariff ($0.42/kWh) and typical Ontario avoided cost ($0.11/kWh) to calculate a net feed-in tariff of $0.31/kWh [9]. In Scenario B the net feed-in tariff is replaced by the difference between typical Ontario and Australian retail prices ($0.06/kWh). This value represents the additional retail price incentive Australians faced to invest in photovoltaic systems even in the absence of

a higher feed-in tariff proposed as part of a standard offer contract in Ontario. A similar sized feed-in tariff ($0.17/kWh or $0.11 + $0.06/kWh) would be required if the Australian price incentives were to be recreated in Ontario. The differences in annual costs are apparent. Scenario B has lower annual costs because it has both lower production and a lower tariff. The shapes of curves A and C are similar with annual costs rising to a peak of $15 million under Scenario A and $25 million under Scenario C in 2016. Annual payments would continue under the 20-year contract and then be renegotiated.

In addition to the net feed-in tariffs, Scenarios B and C include capital rebate programs. A comparison of combined tariffs and rebates is shown in Fig. 6. The rebates in Scenario B follow the Australian pattern of starting at $4/Wp in the first year and declining in a series of $0.10 steps to $3.50/Wp in the last year. In Scenario C the rebates start lower at $3/Wp and then decline $0.30 each year. No size thresholds are applied in calculating rebates. Despite the much larger size of installations achieved under Scenario C, this is achieved with a lower annual rebate and a substantial difference in total rebate expenditure. Total rebates under Scenario B are $73 million, while those under Scenario C are $57 million.

Cumulative tariff costs over the 30-year period total $308 million, $29 million and $507 million under the three scenarios. However, tariff payments are deferred until farther into the future than incentives and adjustments for inflation would reduce these costs in net present value terms. When the capital rebate costs are added to the tariff costs, total payments reach $308 million, $102 million and $565 million over the respective program periods. These total costs should be adjusted for the electricity production generated under each scenario. The resulting average costs are Scenario A—$0.31/kWh, Scenario B—$0.214 //kWh and Scenario C—$0.345/kWh. Scenario B has a lower cost than Scenario A and results in less than half (48%) as much production. Scenario C has costs 11% higher than Scenario A, but also has a 65% larger production capacity and generates 65% more electricity. In summary, greater investment in photovoltaic capacity can be achieved through a balanced market stimulation program that combines contributions from private homeowners, utilities (feed-in tariff) and the government (capital rebate) than relying on a feed-in tariff alone.

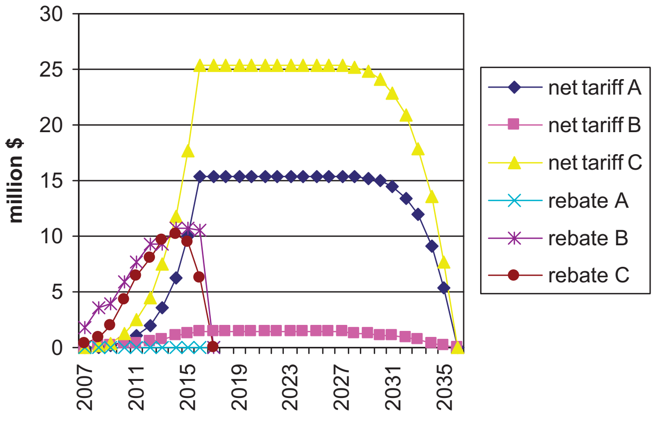

Fig. 6. Annual payments by scenario, million$.

5. Conclusion

The residential market offers substantial growth opportunities to the solar energy industry. A million houses in Ontario have the potential to add solar energy and new houses could have building integrated systems [8,11]. However, the combination of high investment costs and low electricity prices results in very low levels of investment—approximately 50 houses per year in Ontario in 2005. Other countries have stimulated the market through feed-in tariffs and capital incentive programs [32,33]. This paper reviews the experience of Australia and Japan in transforming their residential photovoltaic markets and presents alternate scenarios for consideration in Ontario, Canada.

The Australian photovoltaic industry primarily served off-grid applications, as is the case in Canada. However, a capital incentive program stimulated a shift to the grid-tied segment of the market. A similar shift from the small off-grid market to the large grid-tied market is desired in Canada. In Japan, the national government's residential incentive program succeeded in stimulating market growth from 500 to 50,000 installations per year. The incentive started at 50% of the cost in 1994 and declined to zero in 2006. This decline in incentives was matched by cost reductions as the industry increased its size, improved production techniques, gained efficiency and reduced unit costs. The result was stable customer pricing and growth in demand.

Three scenarios comparing the feed-in tariff, capital rebate and a combined incentive program are presented. Canada and Ontario could combine the lessons from Australia, Europe and Japan with a Balanced Solar Energy Market Stimulation Program that shares the cost of installing residential solar capacity among three key partners: households, government and electrical utilities. The initial capital cost would be divided 70/30 between the households and government (with the government contribution declining over time). A feed-in tariff of $0.42/kWh in a standard offer contract would also encourage investment. The government investment share would decline over the decade while the market stimulation resulted in rapid growth in solar photovoltaic capacity and firms. The experience of national programs in Australia and Japan indicates that an incentive program can be designed to build industry capacity, reduce unit costs and increase market share of grid-tied systems.

Photovoltaic technology offers both the potential to reduce greenhouse gas emissions as a green source of electricity and the potential to develop supply capacity in an industry with rapid global growth prospects. Capital cost incentives proved effective in the Australian and Japanese residential markets. The Canadian government can follow the path of national governments in Australia and Japan and stimulate the market to meet environmental or industry development goals. The Ontario provincial government has decided to take the lead by introducing feed-in tariffs under standard offer contracts because of their responsibility for electricity supply. A program of capital incentives recognizing the public environmental and health benefits of solar energy could be introduced by the national or provincial government to stimulate greater demand and result in the rapid growth of Canada's photovoltaic industry to move it from its current tiny base to one of learning from the global leaders.

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